CONTAMINANTS IN STRIPED BASS

FROM THE FLINT AND APALACHICOLA RIVERS

1986-1989

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by

Diane H. Bateman
Assistant Environmental Contaminants Specialist

Michael S. Brim
Environmental Contaminants Specialist

Gail A. Carmody
Project Leader

U.S. FISH AND WILDLIFE SERVICE
DIVISION OF ECOLOGICAL SERVICES
PANAMA CITY FIELD OFFICE
1612 JUNE AVENUE
PANAMA CITY, FLORIDA 32405
(904) 769-0552

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TITLE: Contaminants in Striped Bass from the Flint and Apalachicola Rivers 1986-1989

ABSTRACT: Five striped bass (*Morone saxitilis*), collected between April 1986 and May 1989 from the Flint River at Albany, Georgia, and the Apalachicola River at Chattahoochee, Florida, were analyzed for chemical contamination. All fish were incidental mortalities associated with the Fish and Wildlife Service's induced spawning and restoration program at the Welaka National Fish Hatchery, Florida. The fish, all female, varied in total length from 908 to 1070 mm and weight from 10.68 to 17.27 kg. Individual fish tissues consisting of unfertilized eggs, mesentery fat, muscle, and liver were analyzed. Analytical results showed elevated levels of metals, polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides, polychlorinated biphenyls (PCBs) and aliphatic hydrocarbons in specific tissues of individual fish.

The presence of particular contaminants in striped bass may contribute to impaired reproductive capacity. Contaminants of primary concern are toxaphene, DDT metabolites, PCBs and mercury. Because of the small number of striped bass evaluated in this project, a more detailed study is required to better define contaminant threats to striped bass.

KEY WORDS: *Morone saxitilis*, striped bass, polycyclic aromatic hydrocarbon, aliphatic hydrocarbon, organochlorine, polychlorinated biphenyls, mercury, metals, organics, Apalachicola River, Flint River.

PREFACE

This study was a cooperative effort involving: the Fish and Wildlife Service's Office of Fisheries Resources, Division of Ecological Services (Environmental Contaminants), Welaka National Fish Hatchery, Florida Game and Fresh Water Fish Commission, and Georgia Department of Natural Resources.

Questions, comments and suggestions related to this report are encouraged. Written inquiries should be directed to the Service at the following address:

U.S. Fish and Wildlife Service
Panama City Field Office
Environmental Contaminants
1612 June Avenue
Panama City, FL 32405

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INTRODUCTION

The Gulf coast striped bass, *Morone saxatilis*, is believed to be a race that is distinct from the Atlantic coast population on the basis of lateral line scale counts and location of capture (Barkuloo 1970). Wirgin, *et al.* (1988) reports that mitochondrial DNA analysis indicates that striped bass collected in the Apalachicola-Chattahoochee-Flint (ACF) river system are a unique genotype not found on the Atlantic coast. The Gulf coast striped bass range in size up to 31 kg (70 pounds)(Mesing, personal communication). The adult striped bass diet consists primarily of clupeid fish (Hollowell 1980) while the larvae and young forage on plankton and crustaceans. The fish tolerate a wide range of salinity. They are temperature sensitive and need cool water refuges during the summer. There are no known records of the Gulf coast striped bass in coastal marine waters (Barkuloo 1970); however, they are frequently found in estuarine waters.

Gulf coast striped bass were historically found in most rivers along the Gulf of Mexico from Lake Pontchartrain, Louisiana, to the Suwannee River, Florida. The population began declining in the 1960s (Barkuloo 1970). Dams preventing striped bass passage to historic spawning grounds and cool thermal refuges, deteriorating water quality due to increased industrialization and development, and accumulation of agricultural pesticides in coastal rivers have all contributed to reduced striped bass survival. Barkuloo (1979) theorized that the heavy use of agricultural pesticides during the 1950s and 1960s probably extirpated striped bass populations in the smaller river systems throughout much of the Gulf coast. During the early 1980s, the U.S. Fish and Wildlife Service (Service) successfully hatched Gulf coast striped bass at the Welaka National Fish Hatchery (NFH), Florida, and began a restoration program based on stocking (Hollowell 1980). This program is accomplished cooperatively with the Florida Game and Fresh Water Fish Commission, Georgia Department of Natural Resources, and Alabama Department of Conservation and Natural Resources.

Personnel from Welaka NFH reported that wild striped bass broodstock collected in the ACF river system for induced spawning exhibited eggs at different developmental stages. Also, a number of females failed to ovulate when hormonally induced, had extended ovulation periods, or produced inferior eggs. Chemical contamination was suggested as a possible cause of the poor spawning

(P. Moon and F. Parauka, personal communication 1994). To test this hypothesis, striped bass were collected and various tissues analyzed to determine the contaminant levels.

SITE DESCRIPTION

All fish were captured downstream of either the Jim Woodruff Lock and Dam on the Apalachicola River or the Albany Power Dam on the Flint River (Figure 1). The Apalachicola-Chattahoochee-Flint (ACF) River basin comprises 51,000 sq km in eastern Alabama, western Georgia, and northwestern Florida (U.S.Fish and Wildlife Service 1987). The Flint and Chattahoochee rivers converge just north of the Florida/Georgia state line to form the Apalachicola River. The Jim Woodruff Lock and Dam impounds the Apalachicola River at its headwaters, forming Lake Seminole.

The Chattahoochee River watershed is predominantly rural with managed pine timberlands in the north and agricultural lands in the south. The central portion of the river near Atlanta and Columbus/Phenix City is highly urbanized. Water is removed from the many reservoirs and impoundments for municipal needs and irrigation and is partially replaced downstream with treated wastewater. The Flint River in Georgia is predominantly rural with agricultural and silvicultural lands abutting the river banks, while the Apalachicola River basin in Florida is sparsely settled with the majority of land in either private or State ownership.

Throughout the watershed, stormwater from agricultural and silvicultural activities, urban runoff, point source discharges from municipal wastewater treatment plants and industry, airborne pollutants, and barge traffic all provide potential sources of contamination. As Gulf coast striped bass apparently do not move into marine waters (salinity $\geq$34 ppt) (Barkuloo 1979), the area in which the bass could accumulate toxicants is primarily limited to the Apalachicola-Chattahoochee-Flint basin.

MATERIALS AND METHODS

In 1986, two striped bass were collected from the Flint River at Albany, Georgia, and one from the Apalachicola River at Chattahoochee, Florida (Table 1). Two additional fish were collected from the Apalachicola River in 1989. Fish were collected by electrofishing gear, transferred to aerated

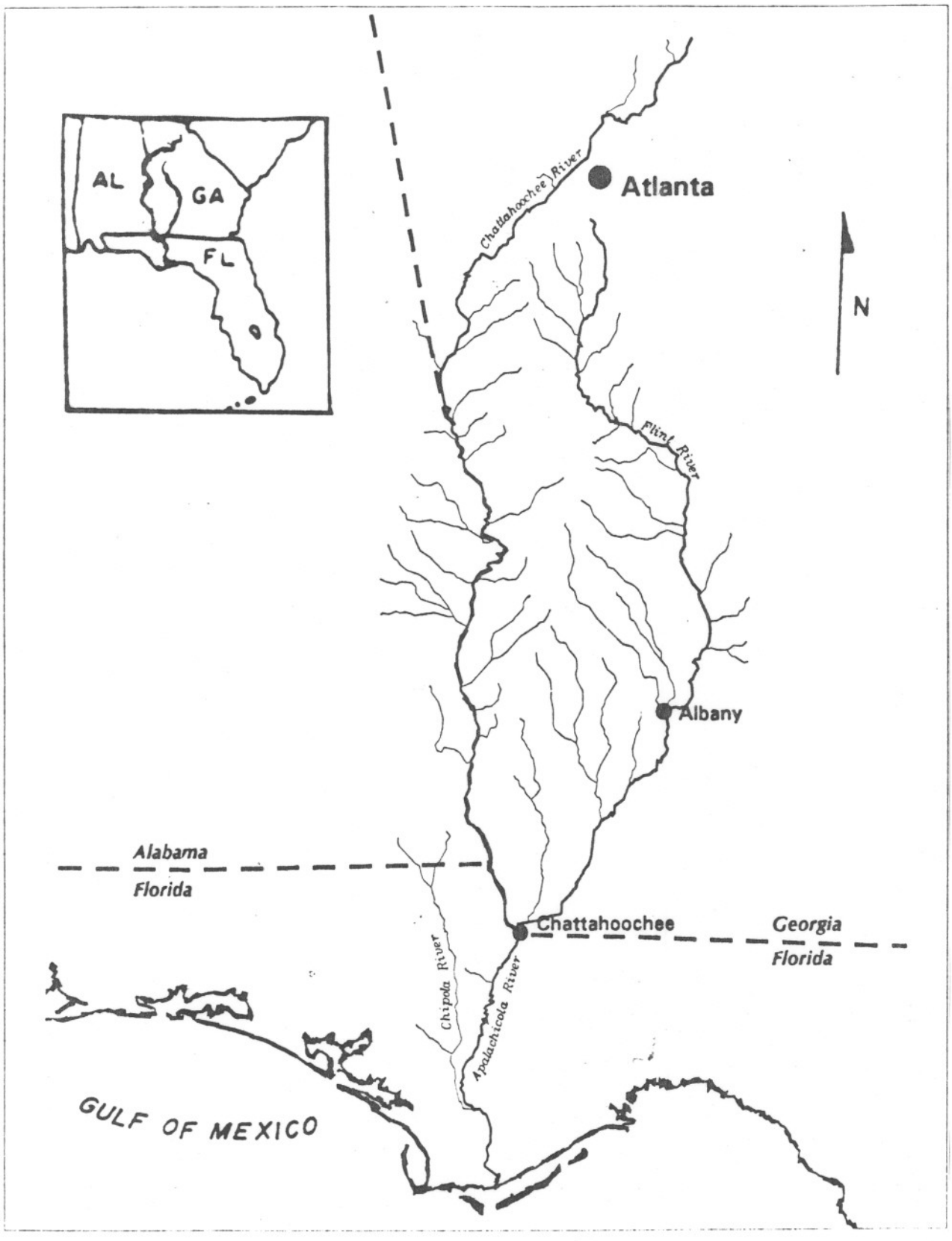

Figure 1. Capture locations of striped bass on the Apalachicola and Flint Rivers.

tank trucks and transported to Welaka NFH for induced spawning. After spawning, the broodstock that did not survive were weighed and measured and then frozen whole until they were dissected. The fish were not aged. Unfertilized eggs, muscle, liver, and adipose tissues were taken from the fish under clean conditions, placed in chemically-clean jars, stored in a freezer at -10° C, and then shipped on dry ice in insulated coolers to appropriate laboratories for analyses.

Metal analyses were performed by Environmental Trace Substances Research Center by gas chromatography/mass spectrometry atomic absorption methods for arsenic, mercury and selenium, and by inductively coupled plasma emission spectroscopy (ICP) with preconcentration for other metals.

Organic compound analyses included organochlorine pesticides, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), and aliphatic hydrocarbons. Analyses were performed by Mississippi State Chemical Laboratory using capillary column gas chromatography (CGC) with electron capture and with a flame ionization detector for aliphatic hydrocarbons, pesticides and PCBs, and a mass spectrometer for aromatic hydrocarbons.

Laboratory quality control was monitored by the Patuxent Analytical Control Facility of the U.S. Fish and Wildlife Service. Study data and tissue moisture values for each sample are presented in the Appendix. Organic concentrations are expressed as wet weight; metals are expressed as both wet and dry weights.

For comparison only, lipophilic organic compounds were normalized to lipid content. Total PCB concentrations are often expressed on the basis of lipid content (Armstrong and Sloan 1988). However, Fabrizio *et al.* (1991) found the PCB-lipid relationship for anadromous species from the Hudson River varied among samples collected in different years or different locations. Fabrizio *et al* did not express total PCB concentrations on the basis of lipid content, because there was no consistent significant relationship between these two factors for striped bass (Brown *et al.* 1985). In view of their research, we have not expressed PCBs in terms of lipid values in this report.

References are made to the U.S. Food and Drug Administration (FDA) tolerance and action levels for consumption by humans. Since striped bass are game fish, and the Service is involved in the restoration of the species, human consumption issues are addressed.

INTERPRETATION CRITERIA

The criteria used to interpret the data were: U.S. Food and Drug Administration (FDA) Action Levels for safe consumption by humans (1992); proposed protection criteria (PPC) for dietary intake by small mammals, birds, or fish as derived from research literature; comparison with the 85th percentile or geometric mean residue concentrations of the Service's National Contaminant Biomonitoring Program (NCBP)(Schmitt *et al.* 1990, Schmitt and Brumbaugh 1990); the Fisheries Resources Trace Elements Survey (FRTES) of the National Marine Fisheries Service (Hall *et al.* 1978); and the consumption advisories for mercury in fishes established by the State of Florida (Florida Department of Health and Rehabilitative Services 1989).

RESULTS AND DISCUSSION

Vital statistics of the fish analyzed are summarized in Table 1.

Table 1. Female Gulf striped bass analyzed for contaminants collected from the Flint and Apalachicola rivers from 1986-1989.

Capture Location	Flint River		Apalachicola River		
ID No.	FL-1	FL-2	AP-1	AP2	AP3
Date Caught	4-3-86	4-3-86	4-4-86	5-2-89	5-2-89
Total Length	980 mm	1070 mm	908 mm	1035 mm	940 mm
Fork Length	930 mm	1020 mm	850 mm	935 mm	900 mm
Weight	14.09 kg	17.27 kg	10.68 kg	16.36 kg	12.27 kg

Metals

Selenium, arsenic, and mercury were detected in every tissue sample in every fish. Aluminum, barium, chromium, copper, iron, manganese, magnesium, strontium, tin, vanadium and zinc were detectable in some tissues at low concentrations. Silver, beryllium, lead, nickel, and thallium were below the level of detection in every sample.

Mercury

Mercury is one of the few metals which strongly bioconcentrates, biomagnifies, has harmful effects, and has no useful physiologic function when present in fish and wildlife. It is a carcinogen, mutagen and teratogen, and is easily transformed from a less toxic inorganic form to a more toxic form in fish and wildlife tissues (Eisler 1987a). Older specimens of long-lived predatory fish, such as striped bass, have been known to accumulate mercury in flesh (Cooper and Vigg 1984).

The U.S. Food and Drug Administration (USFDA) action level for mercury in fish for human consumption is 1 ppm in the edible portion (U.S. Department of Health and Human Services 1992). Florida's health advisories recommend that when the average concentration of mercury in the edible portion (muscle) of fish is between 0.5 and 1.5 ppm ww, healthy adults should limit their consumption to no more than one meal (= 4 oz. or 113.5 gm) of fish per week. Nursing mothers, pregnant women, or those who anticipate bearing children, and children under 15 years of age are advised not to eat these fish more than once a month. Fish that contain more than 1.5 ppm of mercury should not be eaten by anyone (Florida Department of Health and Rehabilitative Services 1989).

None of the five fillets exceeded the FDA action level of 1 ppm, but three exceeded the Florida limited consumption level of 0.5 ppm ww. The arithmetic average for mercury concentration in fillets was 0.52 ppm (Table 2). No apparent differences were noted in mercury concentrations comparing fish from the Apalachicola River to fish from the Flint River, nor were there notable differences in concentrations between the fish captured in 1986 compared to the fish captured in 1989.

Eisler (1987a) recommended that total mercury in food items of avian predators should not exceed 0.1 ppm. However, this level may not be adequate for protection of fish and wildlife resources as mercury concentrations of 0.1 ppm fed to ducks reduced fertility and inhibited food conversion (U.S. Environmental Protection Agency 1980). In addition, chickens fed a diet of 0.05 ppm mercury, accumulated mercury in muscle tissue high enough to be of concern to human consumers (March *et al.* 1983).

Table 2. Geometric (arithmetic) means of mercury concentrations for each river system and each capture year.

	n	ID #	Liver	Fat	Muscle	Ovary
Flint	2	FL1, FL2	.54(.57)	.10(.11)	.55(.56)	.09(.11)
Apalachicola	3	AP1, AP2, AP3	.39(.46)	.04(.05)	.39(.49)	.05(.06)
1986	3	FL1,FL2, AP1	.41(.46)	.06(.08)	.49(.51)	.09(.11)
1989	2	AP2, AP3	.50(.57)	.05(.06)	.51(.54)	.05(.06)

Selenium

Selenium is nutritionally important as an essential trace element, but is harmful at slightly higher concentrations (Eisler 1985a). Reproductive failure in some fish species in the southeast has been linked to selenium contamination when skeletal muscle concentrations ranged from 10 to 50 ppm, ww (Cumbie and Van Horn 1978; Eisler 1985a). Sensitivity to selenium and its compounds is extremely variable in all classes of organisms and, except for some instances of selenium deficiency or of selenosis, metabolic pathways and modes of action are imperfectly understood (Eisler 1985a). Selenium chemistry is complex and its metabolism and degradation in wildlife can be significantly modified by interaction with heavy metals, agricultural chemicals, microorganisms and physiochemical factors (Eisler 1985a).

There is no indication that selenium levels are above normal values in ACF striped bass. The two highest concentrations for selenium were in liver samples from the Apalachicola fish caught in 1989; 3.8 and 2.9 ppm wet weight. The range for muscle tissues in this study was 0.37-0.56 ppm. The striped bass from both the Flint and Apalachicola rivers exhibited roughly the same 1.5 to 3 times higher ovarian to muscle tissue ratio as determined by Cumbie and Van Horn (1978). These researchers also reported that selenium in fish muscle rarely exceeds 1 ppm wet weight in the absence of exposure to selenium from geologic sources or industrial wastes.

Arsenic

Arsenic is present in rocks, soils, water and living organisms at concentrations of parts per billion to parts per million (National Academy of Sciences 1972). Many species of marine plants and animals often contain naturally high concentrations of arsenic. Anthropogenic input of arsenic to the environment is substantial and exceeds that contributed by natural weathering processes by a factor of about three (Natural Resource Council of Canada 1978).

Numerous criteria for arsenic have been proposed for the protection of natural resources and human health. For aquatic life protection, the level of >1.3 mg/kg fresh weight (FW) ppm arsenic residue in muscle of freshwater fish tissue has been proposed. Concentrations greater than 1.3 mg/kg FW resulted in diminished growth and survival in adult bluegill, while certain marine finfish were unaffected by arsenic concentrations of 40 mg/kg FW in muscle tissues (Natural Resource Council of Canada 1978; Eisler 1988). The U.S. does not presently have an action limit for arsenic in fish or fishery products (U.S. Department of Health and Rehabilitative Services 1992).

Arsenic concentrations ranged from 0.12-0.98 (muscle), 0.41-1.45 (liver), 0.40-3.96 (fat) and 0.30-0.99 (egg) ppm ww. The average arsenic concentration for muscle (edible fillet) was 0.46 ppm ww. The concentrations of arsenic observed in this study do not vary greatly from other striped bass field collections (Jenkins 1980; Eisler 1981), and when compared to the proposed protection criteria cited above, do not appear to warrant concern.

Organochlorine Pesticides and Polychlorinated Biphenyls

The high lipid solubility of organochlorine pesticides and their chemical and biological stability results in the bioconcentration and biomagnification of these compounds. The two organochlorine compounds of primary concern in this study were toxaphene and total PCBs. In addition, DDT or DDT-derivatives were detected in every sample. Concentrations of toxaphene, PCBs and DDT are shown in Table 3.

Toxaphene

Toxaphene, a broad-spectrum mixture of compounds, was the insecticide of choice in American agriculture after DDT was banned. Up to 1976, 86% of the 14.1 million kg used annually on major field crops in the United States was applied to cotton. Most use occurred in the southeast, mid-south and southwest (Schmitt et al. 1983). Because of its persistence in water, high acute toxicity to aquatic biota, and significant bioaccumulation and biomagnification characteristics, EPA canceled most registered uses in 1982 (Eisler 1985b). Toxaphene has been associated with growth inhibition, reduced reproduction, backbone abnormalities, and histopathology of the kidneys and gastrointestinal tract in sensitive species of marine and freshwater fish (Eisler 1985b).

Results of the 1978 National Pesticide Monitoring Program showed that toxaphene occurred in nearly all of the fish collected from the Apalachicola River. Species included largemouth bass, channel catfish, and threadfin shad (Winger et al. 1984). In 1986, concentrations of toxaphene (14 ppm ovary, 0.48 ppm muscle) were detected in a Gulf sturgeon (*Acipenser oxyrinchus desotoi*) previously tagged in the Apalachicola River (Bateman and Brim 1994).

Toxaphene was present in all three striped bass tissue samples collected in 1986 from the Apalachicola and Flint rivers, but was absent from both striped bass in the 1989 Apalachicola River samples. Concentrations were lowest in muscle tissue samples and generally highest in fat. Examination of Table 3 reveals that the distribution of toxaphene in body tissues was essentially the same in the three 1986 fish. No concentrations in muscle were near the FDA action level of 5 ppm.

Table 3. Toxaphene, total PCBs, DDT compounds and total PAHs in striped bass tissues. Concentrations are parts per billion, wet weight.

Capture Year	ID No.	Tissue Type	Length (mm)	Weight (kg)	Toxaphene	PCBs	Total p,p'-DDT	Total o,p'-DDT	Total PAHs
1986	FL-1	Muscle	980	14.09	440	120	350	30	0.02
		Liver			2000	1200	1300	100	0.07
		Fat			1600	4600	10680	930	0.63
		Egg			1800	300	1020	100	0.26
	FL-2	Muscle	1070	17.27	350	nd	220	10	nd
		Liver			1600	1100	1400	90	0.06
		Fat			17000	4300	9630	880	0.75
		Egg			1200	nd	580	20	0.04
	AP-1	Muscle	908	10.68	670	nd	320	60	0.01
		Liver			2000	1100	1470	170	0.51
		Fat			13000	2900	6300	770	0.74
1989	AP-3	Muscle	1035	16.36	nd	nd	690	nd	0.11
		Liver			nd	520	7180	nd	0.42
		Fat			nd	7500	1080	nd	0.02
		Egg			nd	nd	200	nd	0.01
	AP-4	Muscle	940	12.27	nd	nd	230	nd	0.20
		Liver			nd	nd	890	nd	0.07
		Fat			nd	1700	500	nd	0.12
		Egg			nd	nd	10	nd	nd

Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) elicit a variety of biologic and toxic effects including death, birth defects, reproductive failure, liver damage, tumors, and a wasting syndrome. They are known to bioaccumulate and to biomagnify within the food chain. Virtually all uses of PCBs and their manufacture have been prohibited in the United States since 1979. In general, the ban has been accompanied by declines in PCB residues in wildlife resources, but PCBs still persist in the environment. PCBs continue to represent a potential hazard to fish and wildlife (Eisler 1986).

In the samples analyzed, PCBs (total) concentrations ranged from below detection to 7500 ppb (Table 3). PCBs were present in fat from all five fish. PCB concentrations in fat were similar for the two rivers and years of collection. In one egg sample, PCBs were 300 ppb. PCB concentrations in livers in 1986 were similar for all three striped bass analyzed (1100, 1100, and 1200 ppb). In 1989 concentrations in liver tissue were below detection in one fish and 520 ppb in the other. The FDA established a tolerance limit of 2 ppm (2000 ppb) for PCBs in the edible portion of fish (J. Jones, U.S. Food and Drug Administration, personal communication). In this study, PCBs were detected in only one muscle sample at 120 ppb, far below the FDA limits.

Eisler (1986) concluded that significant PCB contamination was present when residues exceeded 500 ppb in diet, 400 ppb in whole body, and 300 ppb in eggs. Reproductive impairment in fishes has been observed when ovaries or eggs contained concentrations of PCBs. When PCB concentrations exceeded 120 ppb in ovaries of Baltic flounder (*Platichthys flesus*) and 600 ppb in egg residues from Atlantic salmon, reproductive problems occurred (Ernst 1984; Niimi 1983). Based on these data, possible reproductive impairment in the Flint-1 fish could have occurred because those eggs had a concentration of 300 ppb PCBs. PCBs could represent a significant contaminant problem for some individual fish; however, further sampling would be required to firmly establish impacts related to reproductive toxicity.

DDT, DDE and DDD

DDT (dichloro diphenyl trichloroethane) is a highly persistent organochlorine insecticide that remains from months to years in the environment. Because of its harmful effects to people and wildlife, all

uses of DDT in the United States (except for emergency public health use) were canceled in 1973 (Sine 1992).

In this study, DDT metabolites, p,p'-DDD and p,p'-DDE, were present in every tissue sample, but o,p'-DDE and o,p'-DDT were detected only in the fish caught in 1986 (Table 3). The metabolite o,p'-DDD was not present in any tissue sample. Concentrations for total p,p' metabolites (DDD, DDE, DDT) were highest in the fat samples and ranged from 890-9680 ppb (1150-11740 ppb lipid basis) and lowest in muscle tissue samples 10-350 ppb (410-11300 ppb lipid basis). Concentrations in egg samples were between 230 and 1020 ppb (820-10700 ppb lipid basis). The National Contaminant Biomonitoring Program (NCBP) has shown that, overall, DDT concentrations are in decline (Schmitt *et al.* 1990).

McBay *et al.* (1979) reported that south Atlantic striped bass had total DDT concentrations of 180 to 11,130 ppb in the ova, and from 0 to 1930 ppb in muscle. They attributed observed low spawning success to high concentrations of DDT, PCB, dieldrin, chlordane or toxaphene. However, the concentrations of DDT in the study by McBay *et al.* were not substantially greater than the concentrations reported in this study, 15 years later. The presence of DDT in striped bass eggs could be a factor contributing to hatching failure during induced spawning.

Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons, which originate primarily from petroleum products, have been known to vary considerably in their toxicity to aquatic organisms (Eisler 1987b). The lower molecular weight PAH compounds containing 2 to 3 aromatic rings, have significant acute toxicity to some organisms, whereas the higher molecular weight 4 to 7 ring aromatics do not. However, some members of the higher molecular weight PAH group are known to be carcinogens, cocarcinogens, and tumor producers (Eisler 1987b). Metabolic transformations of PAHs into other hazardous products have been reported to occur in fish and wildlife (Krahan *et al.* 1984; Eisler 1987b). Concentrations of PAHs in fish are usually low because fish can rapidly metabolize PAHs (Lawrence and Weber 1984) and higher weight PAHs do not seem to accumulate in fish (West *et al.* 1984).

Analyses for 14 separate PAH compounds were run on striped bass tissues. PAHs were most concentrated in fat samples, followed by egg samples, and were least concentrated in muscle tissue. Two compounds were of primary concern. Naphthalene, the most commonly occurring PAH in the samples, was present in every liver, egg, and fat tissue sample and in three out of five muscle tissue samples (Table 3). Ranges and arithmetic means (x) were 10-50(28) ppb in liver; 30-100(52) in egg; 40-220(175) in fat; and below detection to 10(8) in muscle for the five striped bass sampled.

Phenanthrene was the next most common PAH. In fat samples, phenanthrene ranged from below detection to 430 ppm (mean=184 ppb).

At present, no criteria or standards have been promulgated for PAHs by any regulatory agency for the protection of sensitive species of aquatic organisms or wildlife (Eisler, personal communication 1994). In view of the carcinogenic characteristics of many PAH compounds, Eisler (1987b) suggested that it would be prudent to reduce or eliminate them wherever possible, pending acquisition of more definitive ecotoxicological data. In view of the above, occurrence of these compounds in any striped bass tissue should be viewed as undesirable; however, because of the mutagenic and teratogenic nature of some of the PAHs, the most harmful effects may occur when concentrations are detected in eggs.

Aliphatic Hydrocarbons

Analyses of 13 alkane, aliphatic hydrocarbons (AH) were run. These are light to medium oil compounds. Excessive quantities of alkane aliphatic compounds in fish tissues may reflect exposure of the fish to large, anthropogenic sources of these materials, i.e., oil spills or industrial discharges. (Moore and Ramamoorthy 1984).

Only the fish caught in 1986 were analyzed for aliphatic hydrocarbons. Examination of the data for total aliphatic hydrocarbons revealed that roughly 1 to 3% is stored in muscle tissue; about 5% in liver; and around 92% in adipose tissue.

Total concentration of AHs and the concentration of n-heptadecane were roughly ten times higher in the Apalachicola River fish than in the two Flint River fish. About 15% of both the total AH and 15% of the n-heptadecane were in liver tissue of the Apalachicola fish, compared to about 5% in the liver tissue of the two Flint River fish. The compartmentalization of more of the AH in the liver may indicate exposure to anthropogenic sources of petroleum products. Additional work involving aliphatic hydrocarbons may indicate whether local groups of striped bass are being chronically exposed to anthropogenic sources of these chemicals. Whether the concentrations found in the Apalachicola fish had any detrimental physiological effect remains undetermined.

SUMMARY

This study was limited to the examination of only five female fish collected during two spawning seasons in two rivers. The data obtained provide a limited view of contaminant conditions existing in striped bass from the lower ACF river system. In addition, since all of the fish were females in the spawning cycle and fat reserves were being depleted, the concentrations of contaminants in the fish may have been skewed.

The striped bass samples had measurable concentrations of several contaminants in all four tissues analyzed. However, it is not known whether these concentrations are representative of contaminant levels that may be affecting ACF striped bass populations. It is known that the eggs from the three Apalachicola River striped bass (AP-1, AP-2 and AP-3) were fertilized but did not hatch (J. Maxwell and F. Parauka, personal communication 1993).

Mercury, toxaphene, PCBs and DDT compounds have been identified as the primary contaminants of concern in this study. Mercury was detected in all striped bass tissues, and three specimens had mercury in edible fillets exceeding the State of Florida 0.5 ppm limited consumption advisory. Toxaphene concentrations were high in all tissues in 1986, and absent in 1989. Quantities of PCBs were present in fish collected during both sampling periods and indicate that this industrial contaminant may still be a problem. Tissue residues of DDT compounds for both collection periods were high enough to warrant concern.

Although reports describing the potential impacts of each of these compounds to biological systems have been reviewed, almost no information exists that defines the cumulative or synergistic threats of these compounds in striped bass. Whereas low levels of the individual contaminants may not constitute significant problems, *the greatest threat to normal embryonic development and survival of larval fish may be the unknown synergistic effects of moderate levels of several toxic chemicals.* Also, many potentially harmful chemicals were not included in our analyses and evaluation. Many industrial and agricultural chemicals could adversely affect striped bass. Among them, the dioxin compounds may deserve special evaluation. Development of any plans for future monitoring of contaminants in striped bass should include careful consideration of additional, potentially harmful chemicals.

RECOMMENDATIONS

1. Develop and implement a striped bass chemical contaminant monitoring program to include:
   a. assessment and quantification of broodstock hatching success,
   b. survival of larval fish,
   c. and evaluation of embryonic abnormalities.
2. Technical components of the program should include:
   a. determination of specific contaminants to be evaluated,
   b. assessment of additive and synergistic effects of toxicants.
3. Program development should include all appropriate state agencies and the Service.

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APPENDIX

Study Data

GULF COAST STRIPED BASS - COLLECTED 1986
METALS - reported in ppm
Environmental Trace Substances Research Center

PCFO ID#	Lab ID#	Tissue	Moist	Sel/DW	Sel/WW	Mer/DW	Mer/WW	Ars/DW	Ars/WW	Alu/DW	Alu/WW	Ber/DW	Ber/WW	Cad/DW	Cad/WW	Chr/DW	Chr/WW
PL-1	PL-1-fl	muscle	76.5	2.1	0.5	1.900	0.447	0.51	0.12	14.0	3.3	<0.01	nd	<0.03	nd	0.30	0.07
PL-1	PL-1-lv	liver	68.7	7.6	2.4	1.200	0.376	1.30	0.41	4.0	1.3	<0.01	nd	0.25	0.08	0.76	0.24
PL-1	PL-1-mf	fat	21.1	0.7	0.5	0.071	0.056	0.51	0.40	1.1	0.9	<0.01	nd	<0.02	nd	0.51	0.40
PL-1	PL-1-eg	egg	73.7	5.0	1.3	0.220	0.058	1.20	0.32	5.5	1.4	<0.01	nd	<0.03	nd	0.10	0.03
PL-2	PL-2-fl	muscle	77.5	2.2	0.5	3.000	0.675	1.00	0.23	2.1	0.5	<0.01	nd	<0.02	nd	0.20	0.05
PL-2	PL-2-lv	liver	70.1	8.6	2.6	2.600	0.777	1.70	0.51	4.7	1.4	<0.01	nd	8.73	2.61	<0.10	nd
PL-2	PL-2-mf	fat	24.5	0.7	0.5	0.220	0.166	0.62	0.47	0.5	0.4	<0.01	nd	0.20	0.15	<0.10	nd
PL-2	PL-2-eg	egg	78.4	4.5	1.0	0.705	0.152	1.80	0.39	6.4	1.4	<0.01	nd	0.24	0.05	<0.10	nd
AP-1	AP-1-fl	muscle	73.5	1.4	0.4	1.500	0.398	0.47	0.12	2.2	0.6	<0.01	nd	<0.02	nd	<0.20	nd
AP-1	AP-1-lv	liver	54.7	2.5	1.1	0.520	0.236	1.90	0.86	2.7	1.2	<0.01	nd	0.17	0.08	<0.10	nd
AP-1	AP-1-mf	fat	14.5	0.2	0.2	0.023	0.020	1.50	1.28	0.4	0.3	<0.01	nd	<0.02	nd	<0.10	nd

				Cop/DW	Cop/WW	Iron/DW	Iron/WW	Man/DW	Man/WW	Nic/DW	Nic/WW	Lead/DW	Lead/WW	Tha/DW	Tha/WW	Zinc/DW	Zinc/WW
PL-1	PL-1-fl	muscle	76.5	1.00	0.24	37.7	8.9	0.52	0.12	0.30	0.07	<0.4	nd	<0.6	nd	9.85	2.31
PL-1	PL-1-lv	liver	68.7	7.24	2.27	170.0	53.2	7.11	2.23	1.70	0.53	<0.4	nd	<0.6	nd	122.00	38.19
PL-1	PL-1-mf	fat	21.1	0.42	0.33	21.3	16.8	0.28	0.22	0.82	0.65	<0.4	nd	<0.6	nd	8.95	7.06
PL-1	PL-1-eg	egg	73.7	5.86	1.54	110.0	28.9	1.40	0.37	5.30	1.39	<0.4	nd	<0.6	nd	108.00	28.40
PL-2	PL-2-fl	muscle	77.5	0.64	0.14	18.0	4.1	0.45	0.10	0.30	0.07	<0.4	nd	<0.6	nd	10.80	2.43
PL-2	PL-2-lv	liver	70.1	8.81	2.63	304.0	90.9	9.24	2.76	10.00	2.99	<0.4	nd	<0.6	nd	117.00	34.98
PL-2	PL-2-mf	fat	24.5	0.47	0.35	46.8	35.3	0.67	0.51	4.30	3.25	<0.4	nd	<0.6	nd	8.93	6.74
PL-2	PL-2-eg	egg	78.4	6.95	1.50	190.0	41.0	1.30	0.28	<0.10	nd	<0.4	nd	<0.6	nd	214.00	46.22
AP-1	AP-1-fl	muscle	73.5	0.82	0.22	21.9	5.8	0.57	0.15	0.30	0.08	<0.4	nd	<0.6	nd	9.94	2.63
AP-1	AP-1-lv	liver	54.7	17.50	7.93	108.0	48.9	5.01	2.27	7.30	3.31	<0.4	nd	<0.6	nd	104.00	47.11
AP-1	AP-1-mf	fat	14.5	0.20	0.17	19.2	16.4	0.37	0.32	<0.10	nd	<0.4	nd	<0.6	nd	3.76	3.21

GULF COAST STRIPED BASS - COLLECTED 1989
METALS - reported in ppm
Environmental Trace Substances Research Center

PCPO	ID#	LAB ID#	Tissue	Moist	Sel/DW	Sel/WW	Mer/DW	Mer/WW	Sil/DW	Sil/WW	Alu/DW	Alu/WW	Ars/DW	Ars/WW	Bor/DW	Bor/WW	Bar/DW	Bar/WW	Ber/DW	Ber/WW
AP-2		SB892E	egg	78.6	5.90	1.26	0.420	0.090	<2.0	nd	<3.0	nd	1.4	1.4	<2.0	nd	<0.31	nd	<0.10	nd
AP-2		SB892F	fat	28.5	0.78	0.56	0.130	0.093	<2.0	nd	3.0	2.1	0.7	0.7	<2.0	nd	<0.10	nd	<0.10	nd
AP-2		SB892L	liver	65.5	11.00	3.80	2.500	0.863	<2.0	nd	8.0	2.8	2.6	2.6	<2.0	nd	<0.10	nd	<0.10	nd
AP-2		SB892M	muscle	72.5	2.40	0.66	2.600	0.715	<2.0	nd	4.0	1.1	3.1	3.1	<2.0	nd	<0.10	nd	<0.10	nd
AP-3		SB893E	egg	62.0	3.80	1.44	0.081	0.031	<2.0	nd	8.0	3.0	2.6	2.6	<2.0	nd	0.100	0.038	<0.10	nd
AP-3		SB893F	fat	22.3	0.57	0.44	0.041	0.032	<2.0	nd	5.0	3.9	5.1	5.1	<2.0	nd	0.200	0.155	<0.09	nd
AP-3		SB893L	liver	56.1	6.60	2.90	0.647	0.284	<2.0	nd	11.0	4.8	3.3	3.3	<2.0	nd	<0.10	nd	<0.10	nd
AP-3		SB893M	muscle	76.0	2.30	0.55	1.500	0.360	<2.0	nd	7.0	1.7	4.1	4.1	<2.0	nd	<0.10	nd	<0.10	nd

PCPO	ID#	LAB ID#	Tissue	Moist	Cad/DW	Cad/WW	Chr/DW	Chr/WW	Cop/DW	Cop/WW	Iron/DW	Iron/WW	Mag/DW	Mag/WW	Man/DW	Man/WW	Mol/DW	Mol/WW	Nic/DW	Nic/WW
AP-2		SB892E	egg	78.6	<0.3	nd	<1.0	nd	5.9	1.3	54.0	11.6	731.0	156.4	0.9	0.2	<1.0	nd	<1.0	nd
AP-2		SB892F	fat	28.5	<0.3	nd	<1.0	nd	<0.2	nd	29.0	20.7	49.9	35.7	<0.3	nd	<1.0	nd	<1.0	nd
AP-2		SB892L	liver	65.5	0.7	0.2	<1.0	nd	9.1	3.1	149.0	51.4	500.0	172.5	4.8	1.7	<1.0	nd	<1.0	nd
AP-2		SB892M	muscle	72.5	<0.3	nd	<1.0	nd	<0.2	nd	3.8	1.0	1010.0	277.8	0.3	0.1	<1.0	nd	<1.0	nd
AP-3		SB893E	egg	62.0	<0.3	nd	<1.0	nd	5.0	1.9	39.0	14.8	417.0	158.5	0.7	0.3	<1.0	nd	<1.0	nd
AP-3		SB893F	fat	22.3	<0.3	nd	<0.9	nd	<0.2	nd	9.3	7.2	85.6	66.5	<0.4	nd	<0.9	nd	<1.0	nd
AP-3		SB893L	liver	56.1	<0.3	nd	<1.0	nd	14.0	6.1	73.0	32.0	390.0	171.2	4.1	1.8	<1.0	nd	<1.0	nd
AP-3		SB893M	muscle	76.0	<0.3	nd	<1.0	nd	<0.2	nd	3.0	0.7	1180.0	283.2	0.4	0.1	<1.0	nd	<1.0	nd

PCPO	ID#	LAB ID#	Tissue	Moist	Lead/DW	Lead/WW	Sel/DW	Sel/WW	Str/DW	Str/WW	Tha/DW	Tha/WW	Van/DW	Van/WW	Zinc/DW	Zinc/WW	Tin/DW	Tin/WW
AP-2		SB892E	egg	78.6	<4.0	nd	<5.0	nd	0.64	0.64	<5.0	nd	<0.3	nd	151.0	151.0	<2.0	nd
AP-2		SB892F	fat	28.5	<4.0	nd	<5.0	nd	<0.10	nd	<5.0	nd	<0.3	nd	6.4	6.4	<2.0	nd
AP-2		SB892L	liver	65.5	<4.0	nd	10.0	3.5	0.20	0.20	<5.0	nd	0.4	0.4	124.0	124.0	<2.0	nd
AP-2		SB892M	muscle	72.5	<4.0	nd	<5.0	nd	<0.10	nd	<4.0	nd	<0.3	nd	9.4	9.4	0.2	0.2
AP-3		SB893E	egg	62.0	<4.0	nd	<6.0	nd	0.43	0.43	<5.0	nd	<0.3	nd	87.1	87.1	<2.0	nd
AP-3		SB893F	fat	22.3	<4.0	nd	<6.0	nd	4.00	4.00	<5.0	nd	<0.3	nd	6.3	6.3	<2.0	nd
AP-3		SB893L	liver	56.1	<4.0	nd	<6.0	nd	0.20	0.20	<5.0	nd	<0.3	nd	106.0	106.0	<2.0	nd
AP-3		SB893M	muscle	76.0	<4.0	nd	<5.0	nd	0.10	0.10	<4.0	nd	<0.3	nd	12.0	12.0	<2.0	nd

GULF COAST STRIPED BASS - COLLECTED 1986 AND 1989
ORGANICS - Reported in ppb wet weight

	1986											1989							
PCFO ID #	FL-1				FL-2				AP-1			AP-2				AP-3			
	FL-1-fl	FL-1-lv	FL-1-mf	FL-1-eg	FL-2-fl	FL-2-lv	FL-2-mf	FL-2-eg	AP-1-fl	AP-1-lv	AP-1-mf	SB892E	SB892F	SB892L	SB892M	SB893E	SB893F	SB893L	SB893M
HCB	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
alpha-BHC	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	60	nd	nd	nd	nd	nd	nd	nd	nd
gamma-BHC	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	40	10	20	nd	nd	nd	30	nd	nd
beta-BHC	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	70	40	nd	nd	nd	nd	nd	nd
delta-BHC	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Oxychlordane	nd	nd	90	nd	nd	nd	100	nd	nd	nd	70	10	80	nd	10	nd	60	50	nd
Hept. Epox.	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	10	130	nd	10	nd	80	110	nd
gamma-Chlordane	10	nd	140	10	nd	30	200	10	nd	40	110	10	80	10	nd	nd	20	50	nd
t-Nonachlor	20	70	610	50	20	110	520	30	20	120	410	60	600	100	20	20	110	90	nd
Toxaphene	440	2000	16000	1800	350	1600	17000	1200	670	2000	13000	nd	nd	nd	nd	nd	nd	nd	nd
PCBs (total)	120	1200	4600	300	nd	1100	4300	nd	nd	1100	2900	nd	7500	520	nd	nd	1700	nd	nd
Mirex	10	50	440	20	10	90	380	10	10	60	200	nd	510	nd	nd	nd	nd	nd	nd
alpha-Chlordane	10	60	360	40	10	90	350	20	10	110	340	50	410	70	10	20	90	60	nd
Dieldrin	10	40	190	30	10	70	360	30	10	90	190	20	160	nd	10	nd	nd	nd	nd
Endrin	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
cis-nonachlor	nd	120	720	50	20	100	790	50	30	140	640	nd	nd	nd	nd	nd	nd	nd	nd
p,p'-DDD	50	80	1600	160	40	100	1700	90	70	170	1100	90	570	110	20	70	200	80	nd
p,p'-DDE	270	1100	8300	790	150	1100	7300	440	220	1300	4700	600	6200	970	180	160	690	420	10
p,p'-DDT	30	120	780	70	30	200	630	50	30	nd	500	nd	410	nd	nd	nd	nd	nd	nd
o,p'-DDD	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
o,p'-DDE	10	100	370	40	10	90	320	20	20	120	330	nd	nd	nd	nd	nd	nd	nd	nd
o,p'-DDT	20	nd	560	60	nd	nd	560	nd	40	50	440	nd	nd	nd	nd	nd	nd	nd	nd
% Moisture	75.60	79.20	24.40	72.20	76.00	72.00	26.70	78.00	72.40	55.50	17.10	70.50	20.00	66.00	73.50	59.00	16.00	56.00	74.50
% Lipid	3.59	16.40	82.40	13.20	1.93	15.80	77.80	5.42	4.46	31.20	87.20	10.20	77.80	17.90	2.92	28.20	77.10	26.00	2.40

Lower level of detection = 0.01 ppm for tissue
nd = none detected

GULF COAST STRIPED BASS - COLLECTED 1986 AND 1989
POLYNUCLEAR AROMATIC HYDROCARBONS - Reported in ppb wet weight

	1986											1989							
PCFO ID #	FL-1				FL-2				AP-1			AP-2				AP-3			
	FL-1-fl	FL-1-lv	FL-1-mf	FL-1-eg	Fl-2-fl	FL-2-lv	FL-2-mf	FL-2-eg	AP-1-fl	AP-1-lv	AP-1-mf	SB892E	SB892F	SB892L	SB892M	SB893E	SB893F	SB893L	SB893M
napthalene	20	20	130	100	nd	20	190	30	10	50	120	30	220	10	10	50	40	40	nd
fluorene	nd	nd	nd	10	nd	10	40	nd	nd	40	20	10	20	nd	nd	nd	nd	10	nd
phenanthrene	nd	50	nd	50	nd	30	360	10	nd	380	430	60	130	nd	nd	130	nd	40	nd
anthracene	nd	nd	20	20	nd	nd	20	nd	nd	10	20	nd	nd	nd	nd	nd	nd	10	nd
fluoranthrene	nd	nd	30	nd	nd	nd	30	nd	nd	20	30	nd	10	nd	nd	nd	nd	10	nd
pyrene	nd	nd	30	20	nd	nd	20	nd	nd	10	30	nd	nd	nd	nd	10	nd	10	nd
1,2-benzanthracene	nd	nd	10	10	nd	nd	10	nd	nd	nd	10	nd	20	nd	nd	nd	10	nd	nd
chrysene	nd	nd	10	20	nd	nd	10	nd	nd	nd	20	10	nd	nd	nd	nd	10	nd	nd
benzo(b)fluoranthrene	nd	nd	10	10	nd	nd	10	nd	nd	nd	10	nd	nd	nd	nd	nd	nd	nd	nd
benzo(k)fluoranthrene	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
benzo(e)pyrene	nd	nd	10	10	nd	nd	10	nd	nd	nd	20	nd	10	10	nd	10	10	nd	nd
benzo(a)pyrene	nd	nd	10	10	nd	nd	10	nd	nd	nd	10	nd	nd	nd	nd	nd	nd	nd	nd
1,2,5,6-dibenzanthracene	nd	nd	10	nd	nd	nd	20	nd	nd	nd	10	nd	nd	nd	nd	nd	nd	nd	nd
benzo(g,h,i)perylene	nd	nd	10	nd	nd	nd	20	nd	nd	nd	10	nd	10	nd	nd	nd	nd	nd	nd
% Moisture	75.60	79.20	24.40	72.20	76.00	72.00	26.70	78.00	72.40	55.50	17.10	70.50	20.00	66.00	73.50	59.00	16.00	56.00	74.50
% Lipid	3.59	16.40	82.40	13.20	1.93	15.80	77.80	5.42	4.46	31.20	87.20	10.20	77.80	17.90	2.92	28.20	77.10	26.00	2.40

Lower level of detection = 0.01 ppm for tissue
nd = none detected

GULF COAST STRIPED BASS - COLLECTED 1986
ALIPHATIC HYDROCARBONS - Reported in ppm wet weight

PCFO ID #	FL-1				FL-2				AP-1		
	FL-1-fl	FL-1-lv	FL-1-mf	FL-1-eg	FL-2-fl	FL-2-lv	FL-2-mf	FL-2-eg	AP-1-fl	AP-1-lv	AP-1-mf
n-dodecane	Ø.Ø1	Ø.Ø4	Ø.19	Ø.Ø4	nd	Ø.Ø3	Ø.12	Ø.Ø2	Ø.Ø1	Ø.12	Ø.16
n-tridecane	nd	nd	Ø.Ø9	Ø.Ø2	nd	Ø.Ø2	Ø.15	Ø.Ø2	nd	nd	Ø.Ø9
n-tetradecane	Ø.Ø1	Ø.Ø2	Ø.13	Ø.Ø4	nd	Ø.Ø2	Ø.2Ø	Ø.Ø2	Ø.Ø1	Ø.15	Ø.12
octylcyclohexane	nd	nd	Ø.Ø4	nd	nd	nd	Ø.Ø4	nd	nd	Ø.Ø5	Ø.Ø5
n-pentadecane	Ø.25	Ø.68	6.5Ø	Ø.33	Ø.16	Ø.62	12.ØØ	Ø.34	Ø.4Ø	3.4Ø	11.ØØ
nonylcyclohexane	nd	nd	nd	nd	nd	nd	Ø.11	nd	nd	Ø.18	Ø.Ø6
n-hexadecane	Ø.Ø3	Ø.Ø6	Ø.91	Ø.Ø4	Ø.Ø1	Ø.Ø5	Ø.84	Ø.Ø4	Ø.22	1.5Ø	6.4Ø
n-heptadecane	1.2Ø	2.3Ø	48.ØØ	Ø.96	Ø.34	1.8Ø	31.ØØ	Ø.6Ø	15.ØØ	84.ØØ	47Ø.ØØ
pristane	Ø.16	Ø.49	3.3Ø	nd	Ø.Ø4	Ø.19	3.7Ø	nd	nd	nd	nd
n-octadecane	Ø.Ø6	Ø.Ø8	2.3Ø	Ø.Ø4	nd	Ø.Ø4	Ø.76	nd	Ø.18	Ø.9Ø	5.3Ø
phytane	Ø.Ø4	Ø.Ø8	1.6Ø	Ø.Ø2	nd	Ø.Ø4	Ø.74	nd	Ø.1Ø	Ø.91	3.3Ø
n-nonadecane	Ø.14	nd	5.2Ø	Ø.Ø8	Ø.Ø2	Ø.Ø4	1.6Ø	nd	Ø.13	Ø.71	nd
n-eicosane	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
% Moisture	75.6Ø	79.2Ø	24.4Ø	72.2Ø	76.ØØ	72.ØØ	26.7Ø	78.ØØ	72.4Ø	55.5Ø	17.1Ø
% Lipid	3.59	16.4Ø	82.4Ø	13.2Ø	1.93	15.8Ø	77.8Ø	5.42	4.46	31.2Ø	87.2Ø

Lower level of detection = Ø.Ø1 ppm for tissue
nd = none detected